AD

Research and Development Technical Report
ECOM-4008

AD 749788

SMALL RADAR CROSS SECTION MEASUREMENTS

ALLAN B. TARBELL

AUGUST 1972

DISTRIBUTION STATEMENT

Approved for public release;
distribution unlimited.

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N J

18

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY *(Corporate author)* US Army Electronics Command Fort Monmouth, New Jersey		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP
3. REPORT TITLE SMALL RADAR CROSS SECTION MEASUREMENTS		
4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)* Technical Report		
5. AUTHOR(S) *(First name, middle initial, last name)* ALLAN B. TARBELL		
6. REPORT DATE August 1972	7a. TOTAL NO. OF PAGES 10	7b. NO. OF REFS 1
8a. CONTRACT OR GRANT NO b. PROJECT NO. 1S6 62704 A188 c. Task N -01 d. Work unit No. -171	9a. ORIGINATOR'S REPORT NUMBER(S) ECOM-4008 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY US Army Electronics Command ATTN: AMSEL-CT-R Fort Monmouth, New Jersey 07703	

13. ABSTRACT

Two methods of measuring radar cross sections as small as $10^{-10} m^2$ are described. The first technique utilizes the return signal from a doppler radar. The second relates radar cross section to variation in VSWR produced by the target when placed in a waveguide. These methods have been utilized to measure the cross section of mosquitoes.

Results of these measurements at both X and Ku-bands are included. Calibration techniques are discussed for both methods of cross section measurement.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

iii

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Radar						
Cross Section						
Small						
X-Band						
K_u-Band						

Reports Control Symbol OSD-1366

TECHNICAL REPORT ECOM-4008

SMALL RADAR CROSS SECTION MEASUREMENTS

by

ALLAN B. TARBELL

Radar Technical Area
Combat Surveillance and Target Acquisition Laboratory

August 1972

DA Work Unit No. 1S6 62704 A188 01 171

Approved for public release;
distribution unlimited.

UNITED STATES ARMY ELECTRONICS COMMAND, FORT MONMOUTH, NEW JERSEY

CONTENTS

FIGURES

TABLE

INTRODUCTION

As a result of studies of atmospheric anomalies, swarms of mosquitoes were suspected to present a detectable radar cross section at X-band. Individual mosquitoes may be detected at higher frequencies. Mosquito cross section data were needed to prove or disprove this possibility. Before such a small cross section could be measured, extreme sensitivity and elimination of spurious responses were required. This report describes different methods for measuring cross sections as small as 10^{-10} m^2. Results of mosquito cross section measurements are included.

DOPPLER METHOD

The first method utilizes a doppler radar to measure cross section. Doppler has one overriding advantage - it responds to moving targets only. Thus, stationary background targets produce no output.

Various techniques for measuring small cross sections with a doppler radar have been attempted. The first, and perhaps most simple technique, involves dropping a target in the beam of the radar. Another technique provides motion by pulling a string to which the target has been attached. While the string technique eliminates much of the body movement of the experimenter near the radar, both techniques still produce enough spurious reflections to obscure targets less than 10^{-5} to 10^{-6} m^2.

The solution must provide target motion radially in the beam without the source of motion producing a return comparable to that of the target. By introducing compressed air into the chamber of Figure 1, such motion is possible. The target, confined by the enclosure, is raised and dropped by the airflow. This motion can be initiated and controlled far from the radar by simply controlling the air velocity. Doppler output is taken from the output of a boxcar detector, filtered, and displayed in time on a storage oscilloscope.

Calibration of this chamber device has been accomplished using steel balls as standard targets. Knowing the diameter of the balls allows the cross section to be accurately calculated.[1] Near field effects do not seem to affect the validity of the results. The calibration curve, Figure 2, is linear, as expected, from the radar range equation. These results, using steel balls, are readily duplicated. Figure 3 shows the doppler from a 3/16" diameter ball used in calibration.

Results of attempts to measure mosquito cross sections with the doppler method have been encouraging, although not as good as desired. Even with a

1 M. Skolnik, Introduction to Radar Systems (McGraw-Hill Book Company, Inc., New York, 1962), p. 41.

sensitivity of 10^{-7} m^2, a single humidified mosquito could not be detected. Trials with many mosquitoes in the tube did produce results. Various numbers of mosquitoes, from three to forty in the chamber at the same time, were used. These data are tabulated in Table I. Peak-to-peak cross sections are given. Peak-to-peak cross section corresponds to the resultant cross section produced when each individual mosquito return signal adds in phase at the antenna producing the maximum possible output. However, these results are not consistent from trial to trial. For example, a ten to one range of cross section from trial to trial was noted with ten mosquitoes in the chamber. For this reason, no conclusions as to the actual cross section of an individual mosquito should be made.

Attempts have also been made to measure the cross section of live mosquitoes using the doppler method. These trials have proven futile. The mosquitoes cling to the inner surface of the chamber and refuse to fly even when coaxed by a blast of air.

WAVEGUIDE METHOD

This method is diagrammed in Figure 4. Readily available equipment is used to produce conclusive values of cross section for individual mosquitoes.

The mismatch of the dummy load must be minimized. In this experiment at X-band, the VSWR of the load was reduced to 1.015:1. This value is low enough to detect targets as small as 10^{-10} m^2. Targets can now be introduced between the slotted line and load, and the new SWR measured. All targets were oriented for maximum reflected power. Calibration is accomplished in a manner similar to that used in the doppler method. Steel balls are used as standard targets. An empirical plot of σ vs. VSWR could be drawn. However, since

$$\sigma = K \, |\rho|^2$$

where K is an experimentally determined constant and ρ is the reflection coefficient found from the measured SWR, a graph of σ vs ρ^2 would be more useful. This curve is plotted in Figure 5. The multiplicative constant, K, is necessary to account for power density which is a function of position within the waveguide.

The value of ρ^2 for the 1/4" diameter ball cannot be expected to follow the square law relation, since 1/4" is an appreciable fraction of the waveguide height. The lower shaded area of Figure 5 indicates the range of cross sections measured for individual dead mosquitoes.

Trials with live mosquitoes were also quite successful. As expected, returns were greater than those from the humidified, dead mosquitoes. Figure 5 shows the range of live mosquito cross sections measured at X-band. Values from 10^{-8} to 5×10^{-8} were obtained.

Mosquito cross sections have also been measured at K_u-band using the waveguide method. At 16 GHz, an increase of approximately 10 dB (over 9.5 GHz returns) was expected. Note that actual returns were 20 dB greater. The extra 10 dB was caused by the larger physical size of this sample of mosquitoes.

The K_u-band data are presented in Figure 6. Plotted values represent the average cross section of five trials.

K_u-band has a distinct advantage over X-band for small cross section measurements. Reflections at K_u-band are stronger making possible the detection of smaller targets at K_u-band than at lower frequencies. By the same reasoning for a given size target, the K_u-band dummy load does not need to be as well matched to the waveguide as does the X-band load.

CONCLUSIONS

The doppler method of measuring small radar cross sections proved unreliable. The waveguide method produced repeatable results with cross sections as small as 10^{-10} m^2.

Using the waveguide method, the cross section of a single, live mosquito has been determined to be 5×10^{-8} m^2 at X-band. K_u-band measurements produced a value of 10^{-6} m^2. For a given radar frequency, variations in cross section of as much as 10 dB can be expected due to differing physical dimensions of the individual mosquitoes.

Table I. Peak-to-Peak Cross Sections Measured Using the Doppler Method.

Number of Mosquitoes	$(\text{Meters})^2$		
	Trial 1	Trial 2	Trial 3
3	1.2×10^{-7}	no return	no return
10	$\sim \frac{1}{2} \times 10^{-7}$	2×10^{-7}	5×10^{-7}
40	3×10^{-7}	10×10^{-7}	10^{-7}

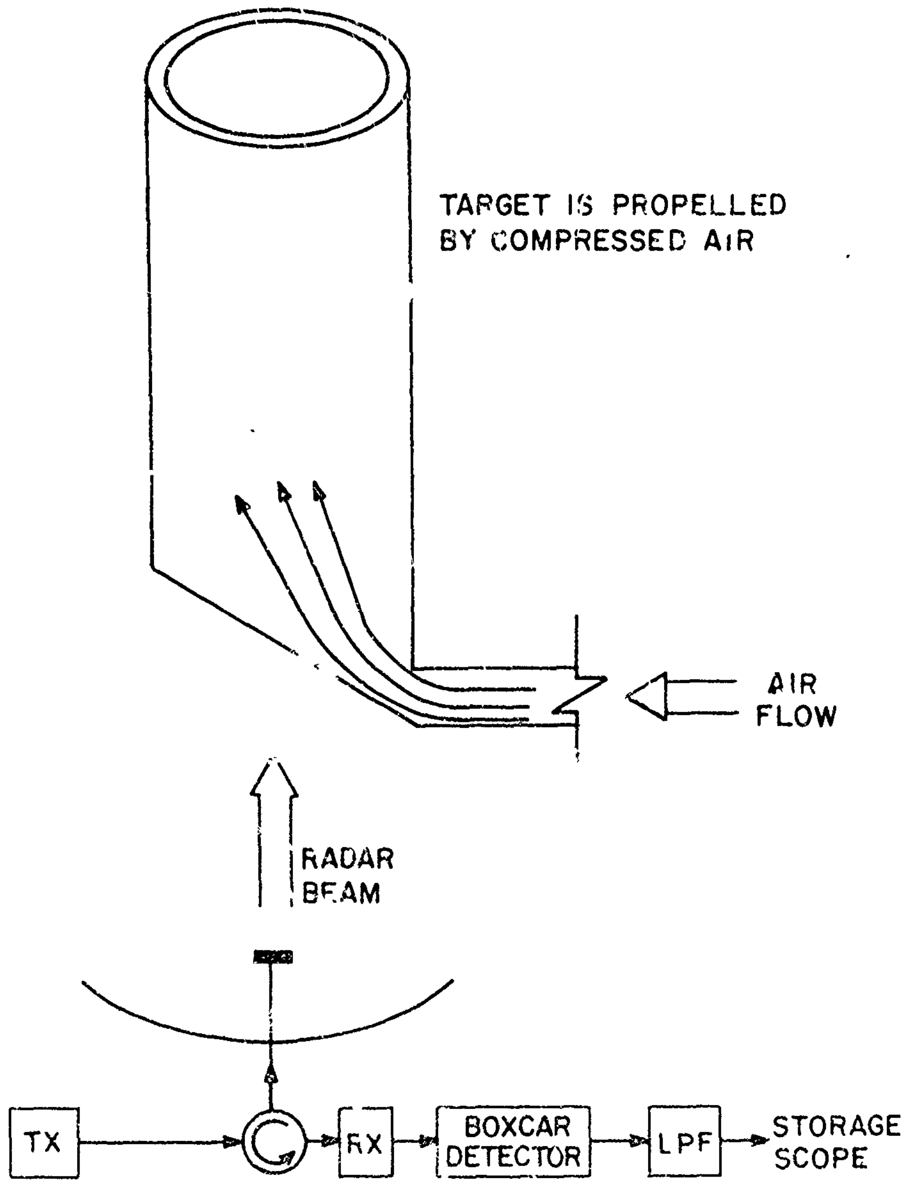

FIGURE 1. DOPPLER TECHNIQUE FOR MEASURING SMALL CROSS SECTIONS

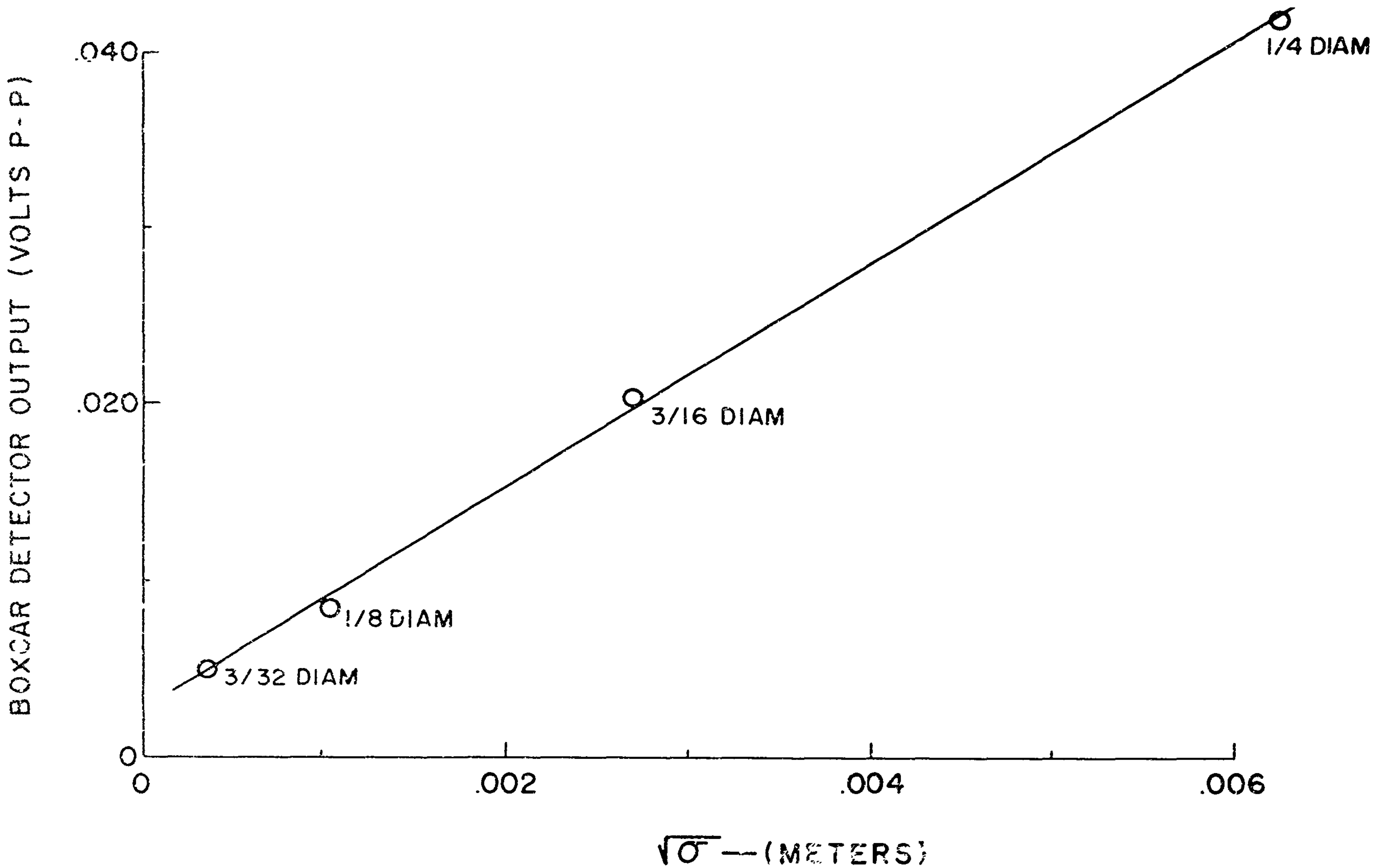

FIGURE 2. CALIBRATION CURVE (DOPPLER RADAR)

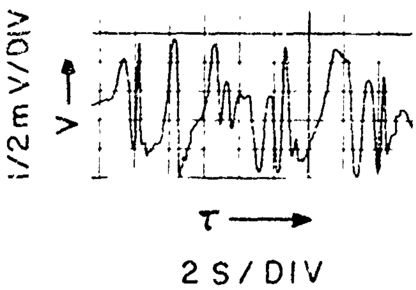

FIGURE 3. BOXCAR DETECTOR OUTPUT VERSUS TIME

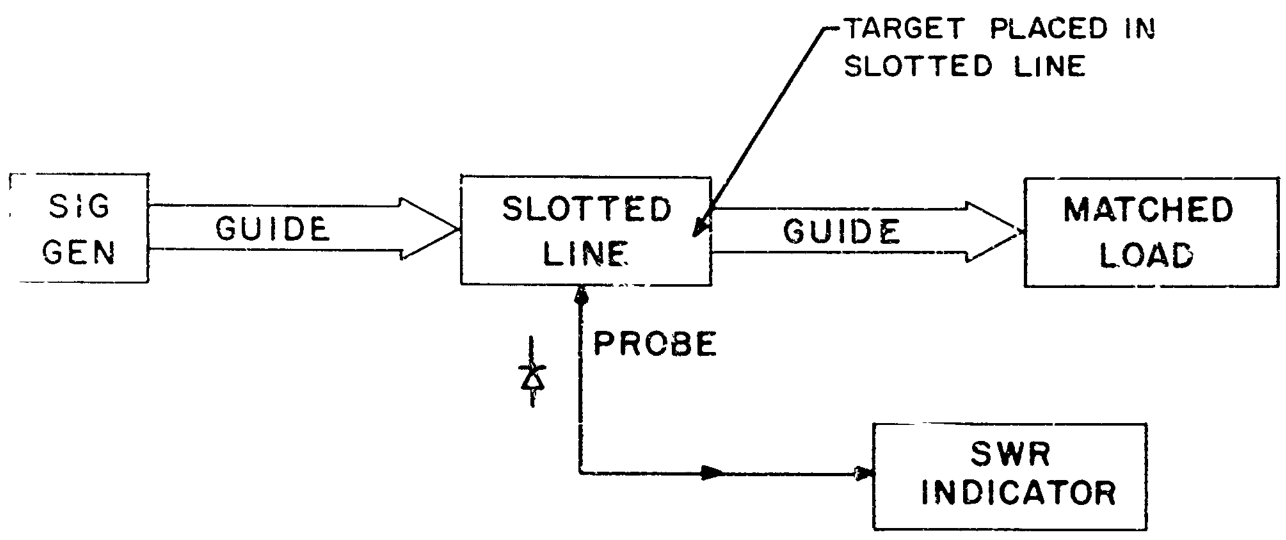

FIGURE 4. WAVEGUIDE METHOD

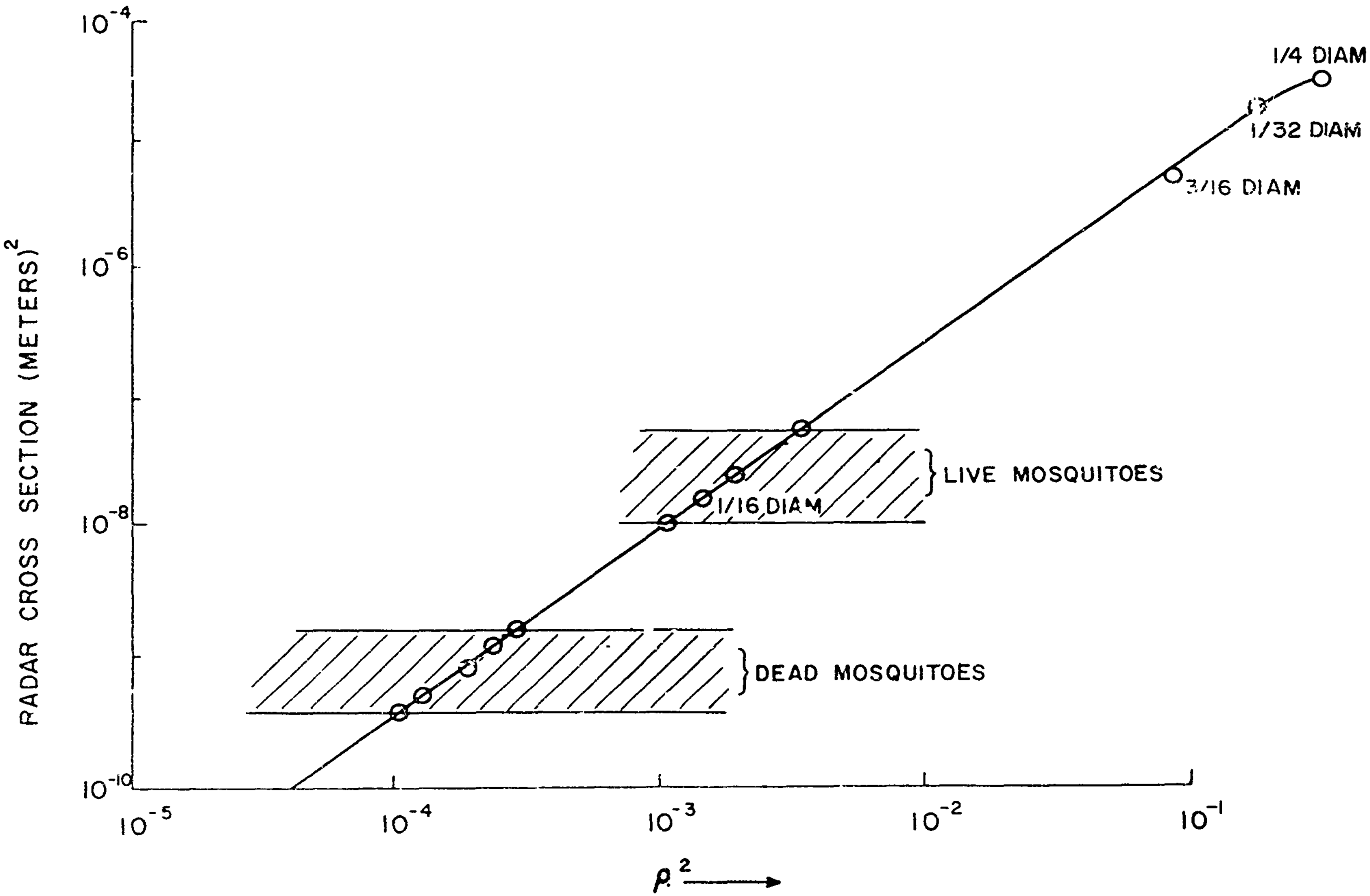

FIGURE 5. X-BAND CALIBRATION CURVE (SLOTTED LINE)

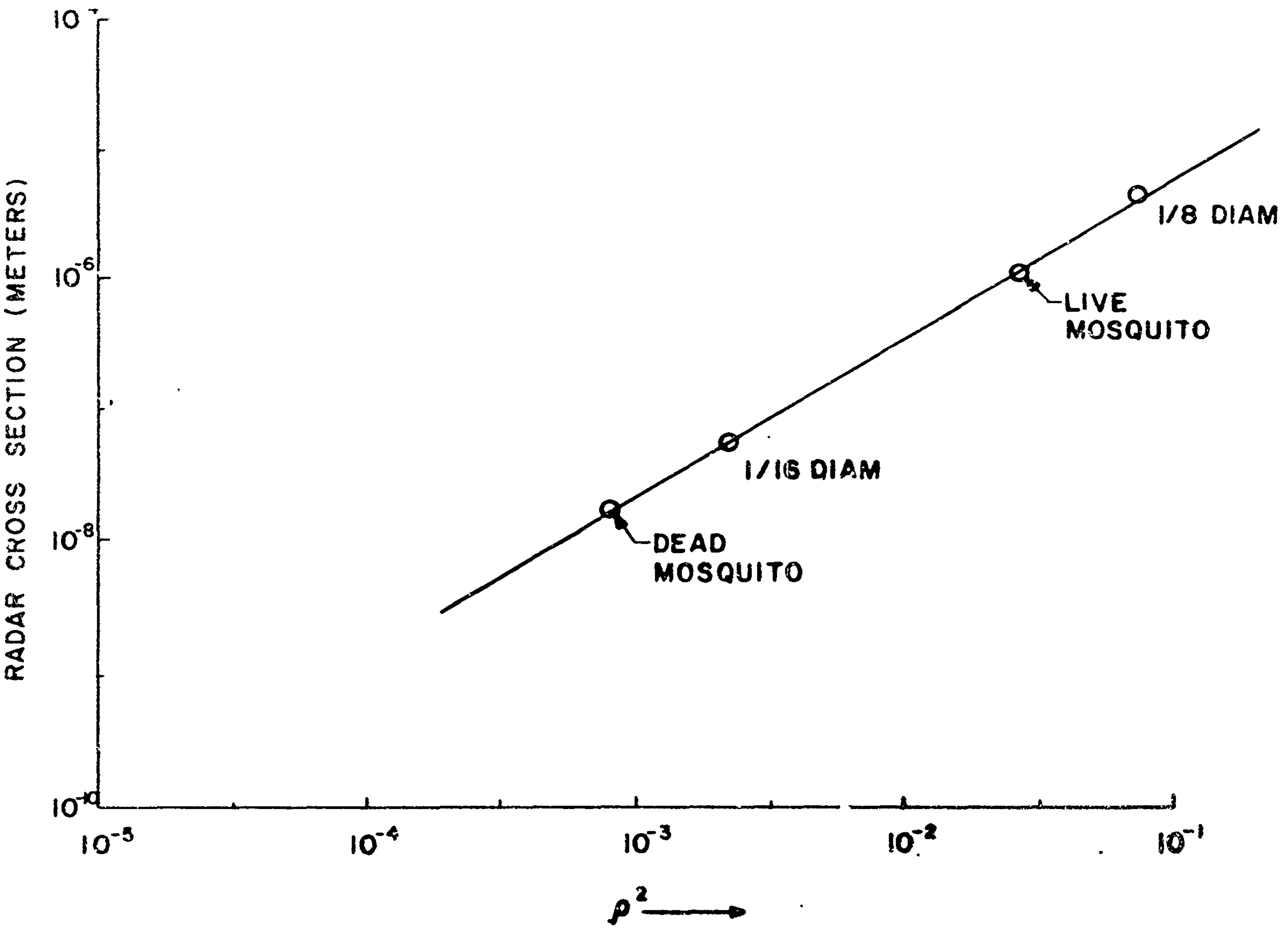

FIGURE 6. KU-BAND CALIBRATION CURVE (SLOTTED LINE)